

Energy Harvesting Bicycle

By

Michael Hui

A Senior Project

presented to

ELECTRICAL ENGINEERING DEPARTMENT

California Polytechnic State University, San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science

December, 2011

©2011 Michael Hui

Table of Contents

I.	Introduction.....	1
II.	Background.....	1
III.	Requirements	2
IV.	Design	2
V.	Construction	6
VI.	Testing	7
VII.	Conclusions.....	14
VIII.	Bibliography.....	15
	Appendices	15
A.	Schematic	15
B.	Parts List	15
	List of Tables and Figures	16

I. Introduction

This project explores energy harvesting with bicycles. With the energy harvested from the bicycle, it will be used to operate the front and back LEDs of the bicycle. Several sources of energy we explore are piezoelectric materials and dynamos.

II. Background

Piezoelectric sensors measure pressure, acceleration, strain, or force and convert them to generate a voltage when the sensor is deformed using the piezoelectric effect. The piezoelectric effect converts the mechanical strain into electric current or voltage. The mechanical strain can come from many sources, such as human motion or low frequency vibrations.

Bottle dynamos are small electrical generators used in conjunction with a bicycle to provide energy. They operate by placing a roller against the side of a bicycle tire. When the bicycle is in motion, the dynamo roller is engaged and energy is generated as the tire spins the dynamo roller. Hub dynamos are small electrical generators that are built into the hub of a bicycle wheel to provide energy. When the bicycle is in motion, the hub generates energy. The advantages of the bottle dynamo over the hub dynamo include no extra resistance when the bottle dynamo is disengaged, easy mounting process to the bicycle, and price. Disadvantages of the bottle dynamo include slippage from rain, tire wear, noise, and positioning.

III. Requirements

The requirements for the energy harvesting bicycle are to find a renewable source of energy to power LEDs used for the headlight and tail light of the bicycle. The LEDs must be bright enough for cars to see at night for the safety of the bicycle rider.

IV. Design

Basic LED headlight

The basic LED headlight requires a dynamo, a bridge rectifier, and a single power LED.

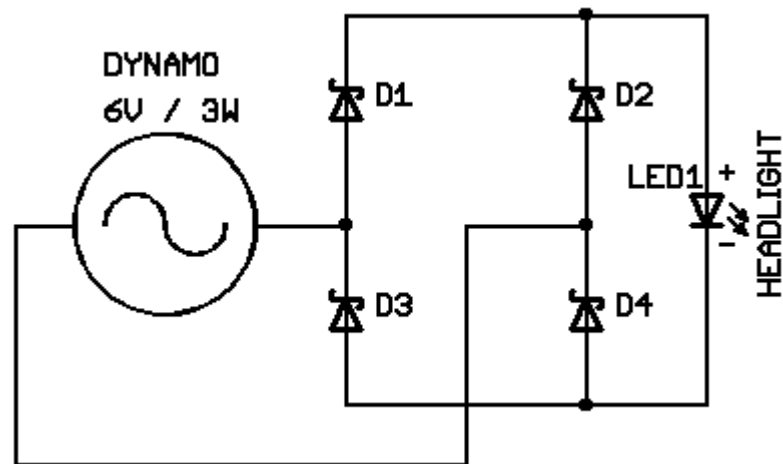


Figure 1: Basic LED headlight.

The AC signal from the dynamo passes through the full-wave bridge rectifier and feeds the single power LED of the headlight. The LED current is limited by the dynamo to 500-600mA. Silicon diodes (1N4007) will work for the full-wave rectifier,

and Schottky diodes (1N5818) will minimize circuit losses. There is one issue with this design: the light from the LED flickers at low speed.

Basic LED headlight with less flicker at low speed

To fix the LED flickering at low speed, a smoothing capacitor can be added in parallel with the LED. It will reduce the flicker and also add a little more brightness from the LED. The larger the capacitor, the less the LED will flicker.

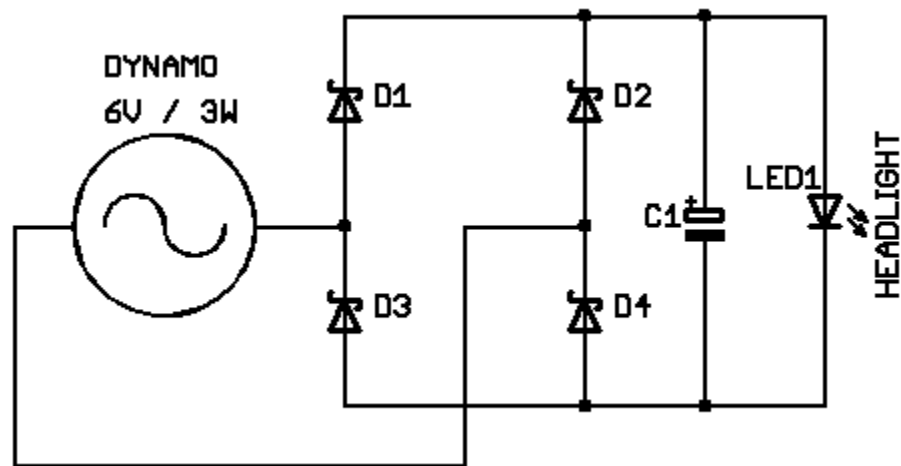


Figure 2: Basic LED headlight with capacitor in parallel.

The capacitor needs to withstand 4V, and there is no upper limit to the capacitor except for cost and size. The capacitor should be mounted within the headlight and properly connected the LED. If the LED disconnects from the circuit, the capacitor will charge to a high voltage. This is not only dangerous to the person riding the bicycle, but upon reconnection of the LED, a peak current will destroy the LED.

Adding a tail light

The tail light LED will take the place of one of the rectifier diodes. As a result, the tail light LED will be driven at half the current of the headlight LED. Since red LEDs have roughly half the forward voltage of white LEDs, the tail light is 25% of the headlight power.

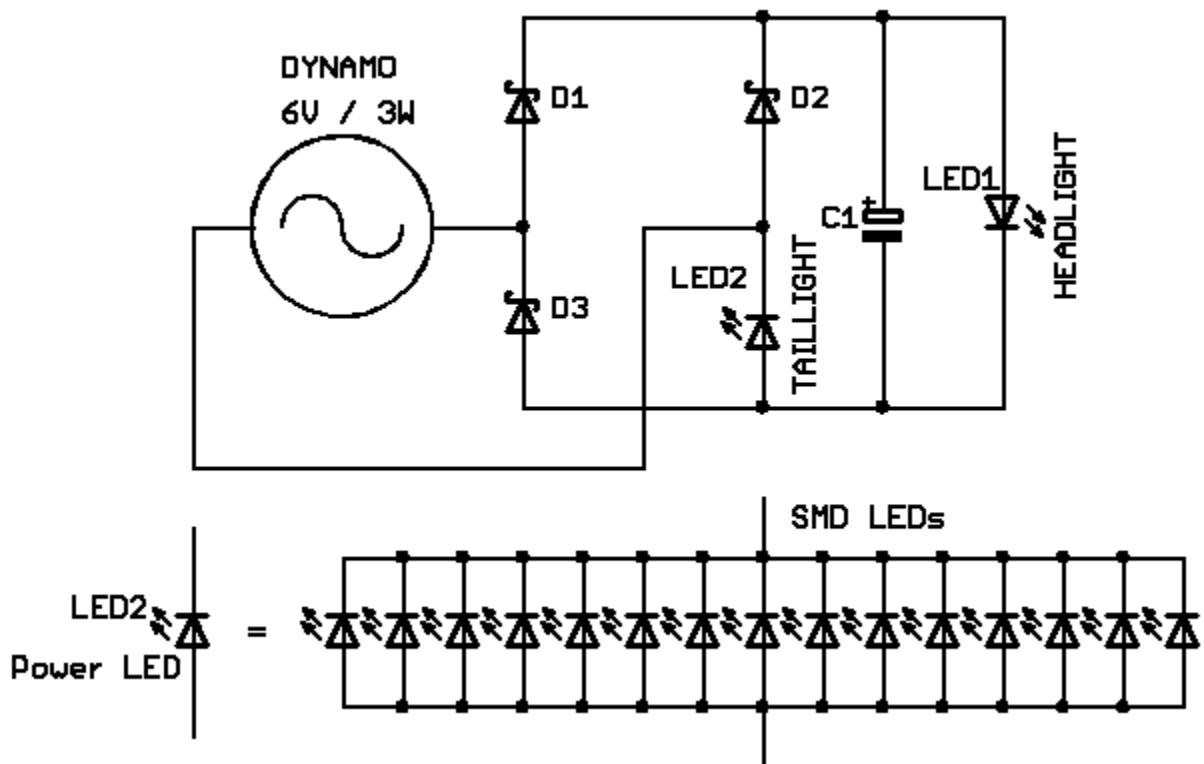


Figure 3: Basic LED tail light.

An alternative to using a power LED for the tail light is to use multiple low-power LEDs in parallel. Any tail light LED has to withstand 5V of reverse-voltage.

Alternative tail light

An alternative way to connect the tail light is shown below in Figure 4. Unlike the circuit shown in Figure 3, where the tail light power is 25% of the headlight power, the tail light power in Figure 4 is adjustable by R1. Using R1, it is possible to dim the tail light to a current low enough for a 4 SMD-LEDs.

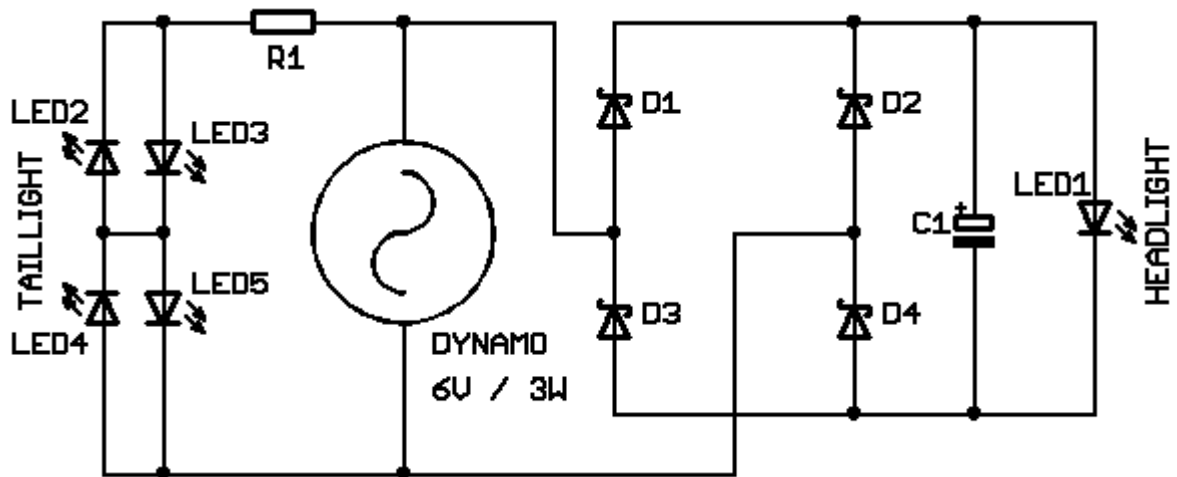


Figure 4: Alternative LED tail light.

Another advantage of this circuit is that the tail light is directly wired to the dynamo terminals. The disadvantages of this circuit are the need to define a resistor value, the lower brightness of the tail light, and that the tail light will be damaged if the headlight disconnects.

V. Construction

Our basic construction was based on the circuit from Figure 1. However, instead of driving only 1 LED, we added many more in parallel to give a brighter light source. we noticed the flicker from the LEDs as the bicycle slows down, so we added a capacitor in parallel, as shown in Figure 2. We mounted the dynamo to the bicycle using the metal clamps to secure it to the bicycle frame as shown below in Figure 5.



Figure 5: Dynamo mounted to bicycle frame.

VI. Testing

We tested both the circuit based on Figure 1, without the capacitor, and the circuit based on Figure 2, with the capacitor added in parallel to reduce the flicker.

We gathered the current and voltages generated at the bicycle's different gears.

Table I: Dynamo Characteristics

Gear	DC Current (mA)	Voltage (V)
1	250	28.1
3	307	31.4
4	320	32.6
5	360	35.4
6	375	36.6
7	400	39

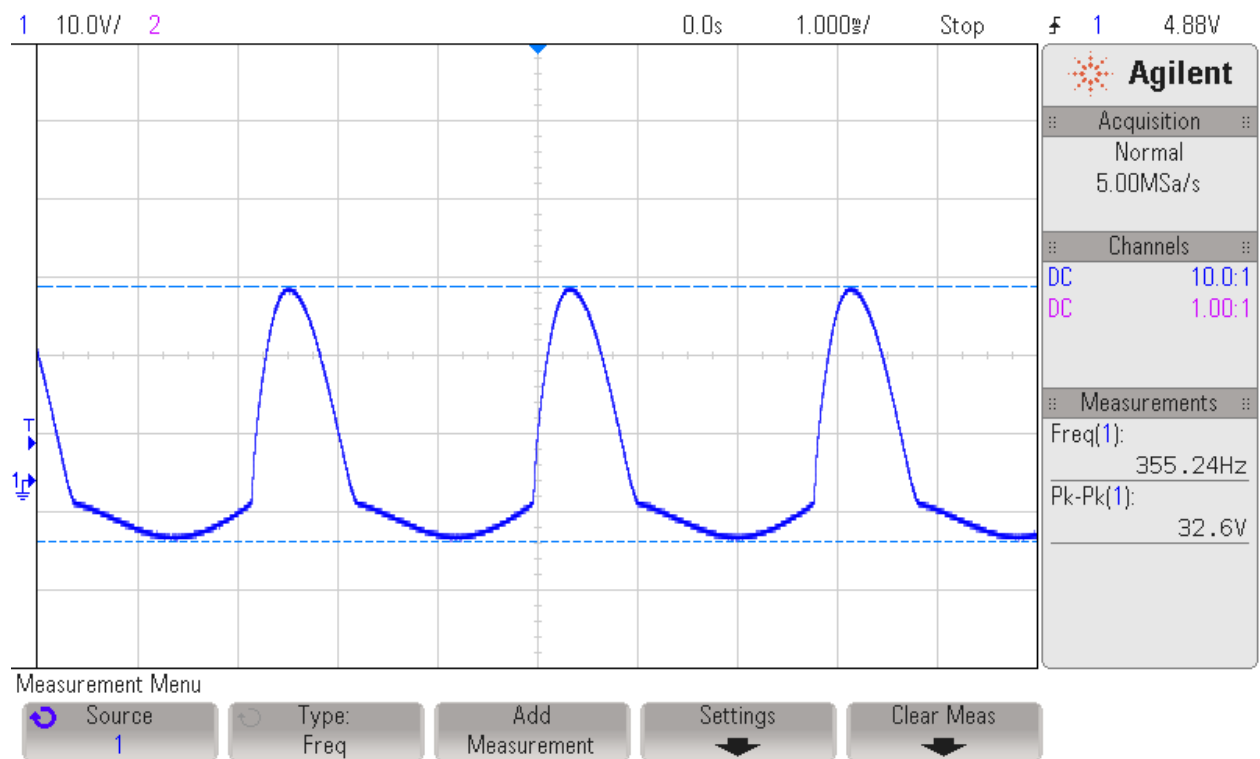
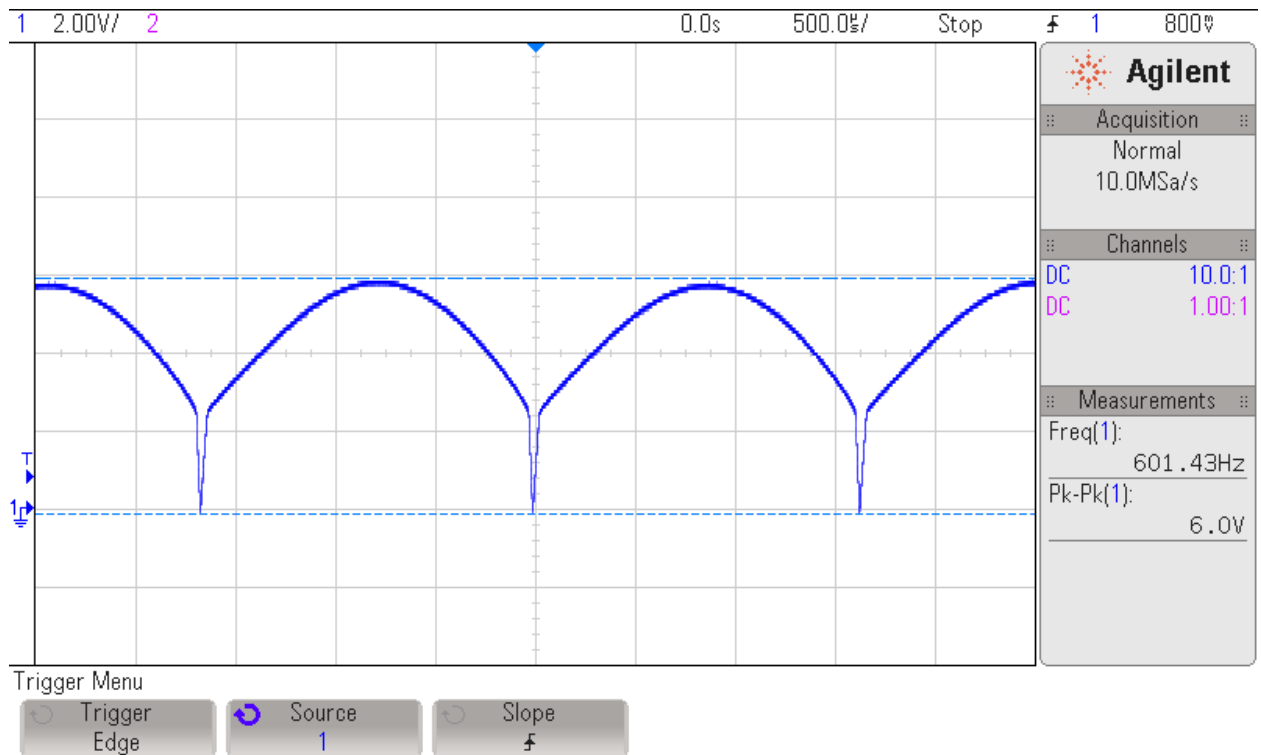


Figure 6: Voltage waveform for dynamo characteristics at gear 4.

These raw input voltages from Table 1 are much too high for what we need, so we built the full wave rectifier to get a more suitable voltage for the LEDs. The voltage waveform from Figure 6 is also undesirable because we do not want the voltage dropping below 0V, and the full wave rectifier will fix that problem as well.

Table II: Full Wave Rectifier

Gear	DC Current (mA)	Voltage (V)
1	310	5.2
3	380	5.9
4	410	6
5	440	6.1
6	460	6.2
7	480	6.4

**Figure 7: Voltage waveform for full wave rectifier at gear 4.**

The full wave rectifier outputs a reasonable voltage level as shown in Table 1.

The output voltage waveform as shown in Figure 7 also no longer drops to 0V.

However, with the full wave rectifier, we noticed the LEDs flickering at low speeds.

We added a capacitor in parallel to help reduce this.

Table III: Full wave rectifier with capacitor

Gear	DC Current (mA)	Voltage (V)
1	320	6
3	375	6.06
4	420	6.22
5	435	6.22
6	465	6.3
7	485	6.22

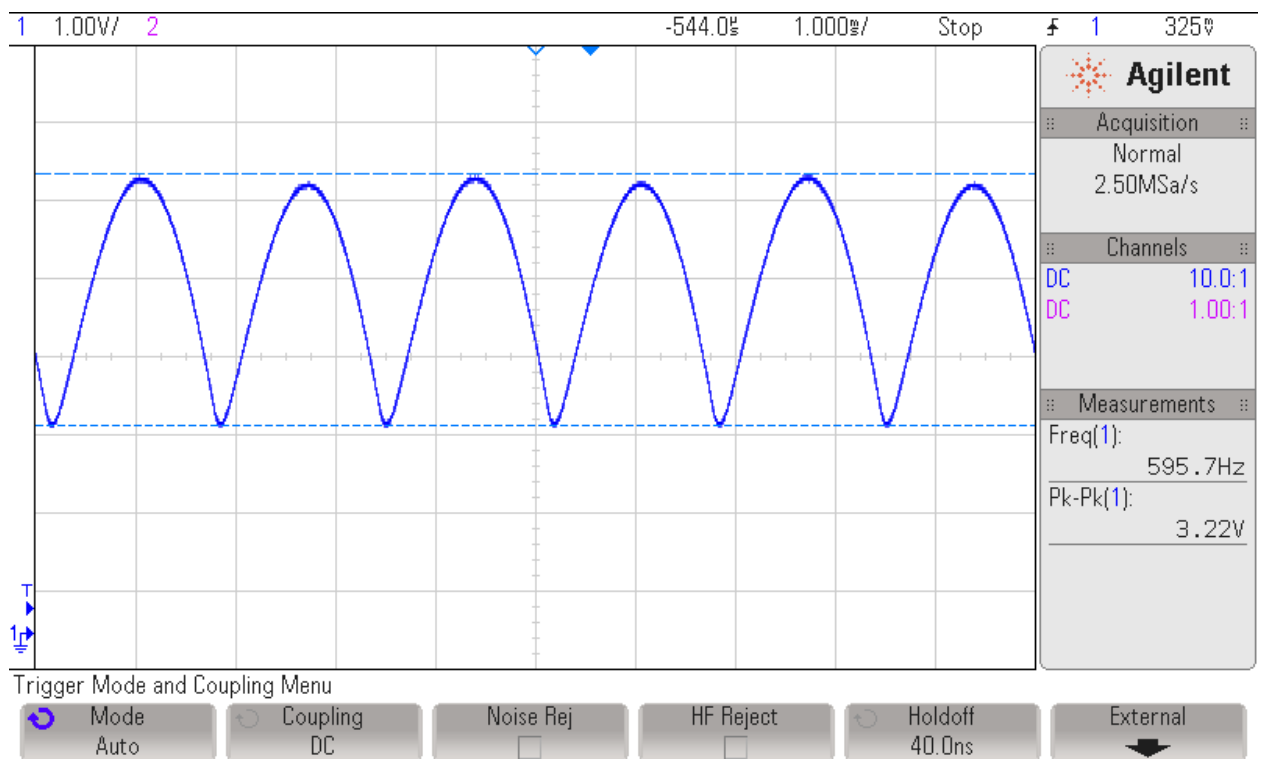
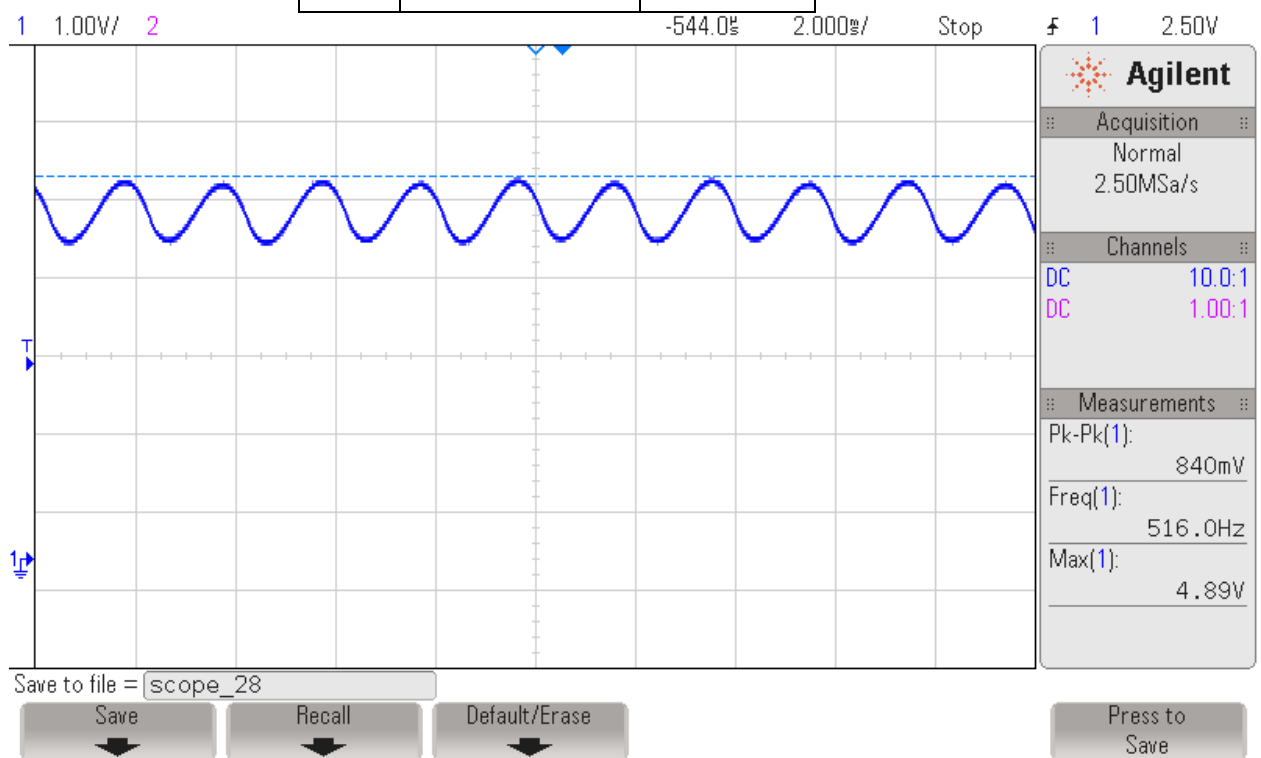


Figure 8: Voltage waveform for full wave rectifier with capacitor at gear 4.

With the added capacitor, the voltage levels still remain capable of turning on the LEDs as shown in Table 3. The output voltage waveform shown in Figure 8 also has a lower voltage ripple than Figure 7. This lower ripple fixes the flickering the LEDs experience at lower speeds. This circuit gave us the best results, however, we had trouble mounting the dynamo to the bicycle. We could not find a position for the dynamo to achieve the maximum power generation without the pedals of the bicycle hitting the dynamo. As a result, we mounted the dynamo on a different bicycle and gathered the data for that bicycle using the circuit with the capacitor in parallel with the LEDs.

Table IV: Full wave rectifier with capacitor using bicycle 2.

Gear	DC Current (mA)	Voltage (V)
1	330	4.72
2	355	4.77
3	370	4.81
4	400	4.89
5	420	4.93
6	450	5.01
7	470	5.05

**Figure 9: Full wave rectifier with capacitor at gear 4 using bicycle 2.**

On the second bicycle, the output voltages were lower as shown in Table 4, but still able to turn on the LEDs. The output voltage waveform from Figure 9 also shows an even lower voltage ripple. With the second bicycle, we were able to get a voltage waveform with a lower ripple while maintaining the same current. The following 2 pictures from Figure 10 show the circuit and how the dynamo was mounted and tested.

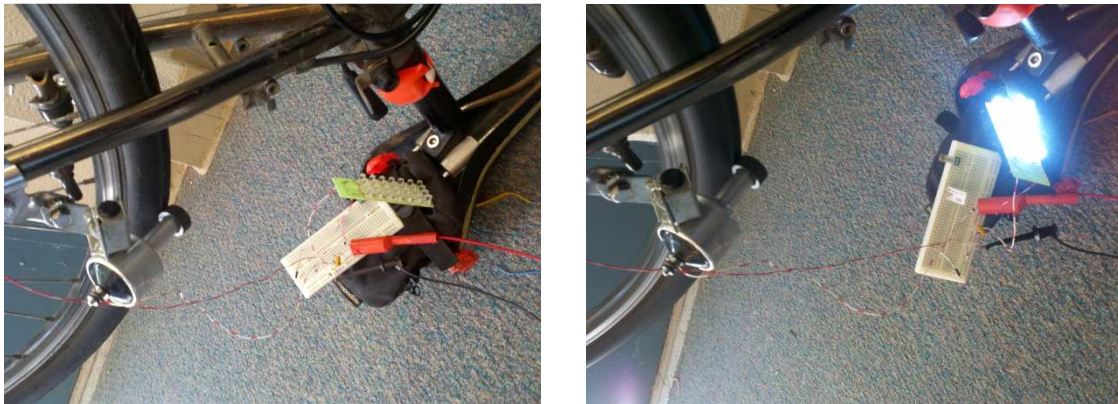


Figure 10: Testing circuit with LEDs off (left) and LEDs on (right).

We tested the headlight LEDs' brightness compared to other headlight sources. Figure 11 shows the headlight LEDs' brightness in a dark environment, compared to other various light sources shown in Figure 12.



Figure 11: Our headlight LEDs.



Figure 12: Other headlight LEDs

VII. Conclusions

The power we can generate using the dynamo is more than enough to power many LEDs for both a headlight and a tail light. We were only able to test it using the headlights, but our results show the brightness of the LEDs surpassing many different battery powered LEDs. This dynamo circuit is capable of supplying enough current and power to power several red LEDs for a tail light.

VIII. Bibliography

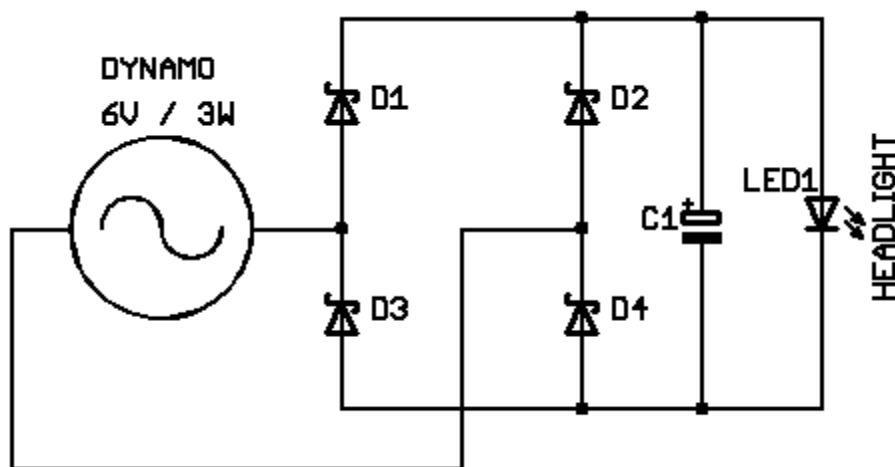
Dr. Dolan, and Dr. Taufik. "Chapter 4 Uncontrolled Rectifiers." *Introduction to Power Electronics*. San Luis Obispo: Cal Poly State University, 2011. 95-152. Print.

Schultz, Olaf. "Bicycle Dynamos." *Pilom Electronics Web Presence*. Web. 29 Sept. 2011. <<http://pilom.com/BicycleElectronics/Dynamo.htm>>.

Schultz, Olaf. "Dynamo LED Light Systems for Bicycles (electronic Circuits)." *Pilom Electronics Web Presence*. Web. 29 Sept. 2011. <<http://pilom.com/BicycleElectronics/DynamoCircuits.htm>>.

Appendices

A. Schematic



B. Parts List

Dynamo

1N4007 Diodes (4)

220 μ F Capacitor

White Power LEDs

List of Tables and Figures

Figures

Figure 1: Basic LED headlight.	2
Figure 2: Basic LED headlight with capacitor in parallel.....	3
Figure 3: Basic LED tail light.....	4
Figure 4: Alternative LED tail light.	5
Figure 5: Dynamo mounted to bicycle frame.....	6
Figure 6: Voltage waveform for dynamo characteristics at gear 4.	8
Figure 7: Voltage waveform for full wave rectifier at gear 4.	9
Figure 8: Voltage waveform for full wave rectifier with capacitor at gear 4.	11
Figure 9: Full wave rectifier with capacitor at gear 4 using bicycle 2.	12
Figure 10: Testing circuit with LEDs off (left) and LEDs on (right).....	13
Figure 11: Our headlight LEDs.	13
Figure 12: Other headlight LEDs.....	14

Tables

Table I: Dynamo Characteristics.....	7
Table II: Full Wave Rectifier.....	9
Table III: Full wave rectifier with capacitor	10
Table IV: Full wave rectifier with capacitor using bicycle 2.	12